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ECONOMIC GEOLOGY

ABSTRACT OF LECTURES

BY

S. G. WILLIAMS,
Professor of General and Economic Geology
CORNELL UNIVERSITY

ITHACA, N. Y.:
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Economic Geology.

1. Defined—as that department of Geology which treats of such products of the Earth's crust, and such structural characters, as minister to human wants, or tend to civilization and culture.

2. It aims:

a. At a knowledge of those structural characters which must be taken into account to make human efforts more effective.

b. At an accurate and extended knowledge of those special geological deposits which have practical utility.

c. At ascertaining the practical and often essential relations which these deposits bear to each other; e. g., ores to fuels and fluxes.

d. At knowing the relations they bear to the currents of human industry and to present or prospective human needs; e. g., ease of access and transportation; means of smelting; means of profitable utilization; e. g., Petroleum vs. Seneca oil; Pyrites past and present; Nickel since used for plating.

3. Requisites for profitable study:

a. Knowledge of geological structure of the earth and its rocky masses, and of their arrangement.

b. Elementary knowledge of Mineralogy and Lithology.

c. Knowledge of geography.

STRUCTURE.

1. Earth's structural characters are an evolution of the varied, the complex, the specialized, out of the simple, uniform, general,—as to outlines of land, relief-forms, climate and productions:

a. Illustration of first two points leading to idea of plains and mountains, resting on a foundation of rocks.

b. That the loose materials resting on these arise from the disaggregation of rocks; agencies of frost, CO^2 etc.

c. That these loose materials resting in place, or deposited on land, constitute soils.

d. That those carried and deposited layer on layer in water, form rocks whether hard or soft. How consolidated.

e. That hence most rocks are not simple things, but more or less indefinite aggregates.

f. That also most rocks originated as sediments, mechanical, organic or chemical, and carry proof of this in their character and contents. (See beyond.)

2. Structure and arrangement of rock masses (Dana 79: Lec. 20 and 170):

The first thing that is apt to strike an observer is that the vast majority of rocks are arranged in successive sheets piled one on another. Note:

(1) Structure of sheets as (thin or thick—economic import; massive or laminated—economic import.

(2) Their texture as fine or coarse or compact—import.

(3) Their varying composition of sand, clay, lime.

(4) Their contents, water marks, fossils, etc.

3. Illustration of above by showing how rocks are now forming:

a. By wear and solution.

b. By deposition (mechanical or chemical) and assimilation.

4. Structural characters of economic importance.

a. Jointed, relation to—1. Ease of quarrying. 2. Size of forms.

b. Concretionary, an ill to be avoided.

POSITION, ETC.

1. Original position of stratified rocks, horizontal.

2. Changes from this original position, uplifts, etc., and how caused.

3. What happens to rocks when uplifted. Denudation and effects on accessibility (Leconte, 260.)

4. Terms to be mastered arising from uplifts :

a. Dip, effects on accessibility and width of outcrop.
b. Strike.
c. Anticlinal- synclinal- monoclinal folds.
d. Faults, economic aspects, law of.
e. Conformability (Dana, 91; Leconte, 171–179.
5. Relative age of stratified rocks, determined:
a. By superposition.
b. By rock characters.
c. By fossils (Dana, 101; Leconte, 195–200; Geikie, 614–622,)
6. Geological column (Dana, 139–143; Leconte, 201.)

Crystalline Rocks.

1. Condition and how consolidated (welded, interlocked, felted.)
2. Mode of occurrence:
a. In layers more or less distinct, but usually folded or tilted up at high angles—Metamorphic.
b. Massive or unstratified—all marks of deposit obliterated; often squeezed into fissures in other rocks; e. g., Granite, etc.
c. Dike-form; fissures filled with melted rock.
d. Veins; fissures filled by watery deposit, etc.
3 Texture of these, crystalline, or earthy from decomp.
a. Coarse crystalline; e. g., mica mines.
b. Fine crystals, important for durability and strength.
c. Glassy, sometimes in dikes, cause of.
d. Aphanitic, imperceptibly small crystals.
e. Porphyritic, crystals imbedded in aphanitic base.
4. Structural characters of economic import:
a. Schistose (foliated) and massive: economic relations.
b. Jointed: economic relations.
c. Slaty cleavage, in what rocks: economic relations.
d. Columnar, relation to joints: economic relations.
e. Banded, of veins.
5. Relative age of unstratified rocks, dikes, and veins shown by:
a. Superposition or overflow.

b. Intrusion or cutting, with 1. Alteration of cut rock. 2. Faulting of cut rock.

c. Included fragments of older rocks.

d. Mineral characters and relative decomposition.

e. Organisms, in volc. tuffs or beds overflowed by volcanics.

f. Metamorphics usually older than other stratified rocks, underlying them unconformably.

g. Veins younger than country rock or than veins they cut.

◆

Vein Structure and Ore Deposits.

1. References: Dana, 770; Leconte, 225; Lyell, 605; Raymond Rep., 1870, p. 447–468; C. King, Vol. 3; Von Cotta, Erzlagerstätten, p. 102–190.

2. Valuable mineral deposits and ores occur, as:

a. Stratified, *i. e.*, bedded (1. Placers or other superficial deposits. 2. Forming entire strata, coal, iron. 3. Disseminated in, Mansfeld copper schists; L. Superior S. S.'s. 4. Segregated from, clay iron.)

b. Stöcke: irregular veins or beds, or fillings of cavernous spaces found in rocks.

(1) Gash veins and caverns only in Limestone; e. g., lead deposits of Mo., Wis., and Ill., filled from surrounding rock: called rakes and sometimes pipes.

(2) Quasi Veins, chambers or pockets (Newberry): filling irregular chambers in lime, connected with deep-seated fissures through disturbances, and filled from below; e. g., Eureka mines; Emma mine.

(3) Contact deposits: along planes of contact between rocks of different kind; e. g., Leadville deposits are chambers at junction of porphyry and underlying lime; also flats of Flintshire are in chambers of S. S. lying over lime and connected with fissures. All such deposits have pretty definite outlines, however irregular they may be.

c. Impregnations: these are either (1) infiltrations of ore-bearing solutions into beds; e. g., Silver-Reef silver S. S.; copper traps and conglomerates of Lake Superior; cinnabar mines: (2) contact zones by side of other deposits from which they were enriched either contemporaneously or subsequently; e. g., Fresnillo mines at Zacatecas, composed of a stockwerk with country rock enriched from 6″ — 30″.

Impregnations have no definite boundaries save the limits of profitable working.

d. Veins are sheets of mineral matter differing more or less from the enclosing or country rock and filling somewhat definite fissures in it.

(1) Granite veins: irregular intrusions of granitic matter into other rocks; often very large.

(2) Segregated veins: lenticular masses chiefly of quartz, formed by elimination of their material from surrounding metamorphic rocks, conforming to their bedding, and sometimes containing pyrite and chalcopyrite with gold; allied closely to stöcke.

(3) True fissure veins fill fissures often of great length and extending to unknown depths, and have usually been filled from below by chemical processes of solution or sublimation.

Where a vein contains valuable ores it is often called a lode.

3. Vein fissures occur mostly in disturbed and in metamorphic rocks, and in the vicinity of igneous agencies, owing their origin evidently to disturbances of the crust.

They are often coincident with Faults causing irregularities of width.

The fissure may—(1) cut across the planes of bedding where these are visible; e. g., gold veins of Gilpin Co., Col.; (2) coincide chiefly with bedding planes forming bedded veins, as is common in schistose rocks of high dip; when distinguishable from bedded deposits and segregated veins, it must be by their having fissure vein characters; (3) Coincide wholly or in part with junction of two different and unconformable formations, called contact veins; e. g., Comstock vein along Mt. Davidson.

The vein fissures of a region are usually rudely parallel, having been formed by the same set of forces; e. g., veins of Gilpin Co., nearly E.-W.; Reese River, Nev., N. W,, etc.

The Dip or Hade varies from vertical to flat; e. g., Comstock, 45°; Gilpin Co. veins, 80° to 90°; hanging wall and foot wall.

4. The contents of veins are:

(*a*) Gangues or vein stones, most common being Quartz, Calcite, Baryte, Fluorite.

(*b*) Metallic ores, which sometimes fill the entire vein, as occasionally pyrite, chalcopyrite and galena; but usually form but a small part as bands, strings, or thin filaments, pockets or lumps, grains or threads, linings of druses; e. g., of small amount, silver worth $16.00 a lb. *i. e.*, $14\frac{7}{12}$ oz. Troy; hence a $160 ore carries 10 lbs. per ton $=\frac{1}{200}$ or $\frac{1}{2}$ of one per cent. The most common metallic sources are, (1) metals, as gold, silver, copper; (2) sulphides, as galena, blende, argentite; (3) carbonates, as smithsonite, malachite, etc.; (4) oxides, as cuprite, cassiterite, Zincite; (5) chlorides, as cerargyrite; (6) silicates, as calamine, pimelite. Bonanzas are rich zones in veins.

c. Horses or riders; fragments broken from the walls or torn off in reopening of vein by movements.

d. Fluccan, selvage or gouge; ground up or decomposed material of walls or veins, lining one or both walls.

5. Vein structure and phenomena:

a. Arrangement of vein matter may be—

(1) Massive, as in case of one material, quartz, pyrite, etc.;

(2) In banded and often duplicated layers, with materials in successive sheets parallel to walls;

(3) Brecciated, fragments of country rock imbedded with gangue and ores; e. g., Bassick mine, Col.;

(4) Drusy, open cavities at centre of vein;

(5) Filamentous, thread-like veins traversing gangue, common;

(6) A stock-work is a portion of "country rock" so charged with interlaced veins, nests, etc., as to be mined out as a whole.

b. Veins pinch and swell, a phenomenon caused by movement in the walls of an irregular fissure.

c. Veins often show signs of movement since their formation and filling, in (1) slickensides, (2) selvage or gouge, (3) successive combings from reopening.

d. Parallel veins of a region are apt to have similar contents;

and when coursing differently somewhat different contents, exc. some at right angles.

e. A change of the country rock is apt to be attended by some change in vein contents or richness, whether from difference of conductivity, or of porosity, or of roughness, or of chemical reactions between fluids and rock (V. Cotta, p. 149.)

f. Veins crossing at a small angle are apt to be richer at the crossing, possibly from reactions of different solutions.

g. Veins apt to be richer at widest parts, whether (1) from retardation of flow of metalliferous solutions; or (2) from formation of more bands of deposits (V. C. 131.)

6. Veins like strata, liable to be faulted by fissures:

a. The faults of a region apt to have the same course and the same direction of downthrow, as if produced by the same cause; e. g., Reese R. region largely faulted by narrow N. and S. fissures.

b. Usual law of fault is that the hanging wall of the faulting fissure goes down, *i. e.*, it hades to the downthrow.

7. Surface appearances, gossan, iron hat. These are a result of atmospheric agencies of change, altering sulphides to oxides, carbonates, chlorids, and hydrates; accompanied by vivid colors with development of native silver and Cu. Those holding sulphides with iron have most marked appearances.

a. Along the back of copper veins we find gangue with spongy iron oxide (iron hat), and in lower depths $Cu_{\_}$, $CuCO^{3}_{\_}$, oxides of Cu.; e. g., Ducktown mines.

b. In lead deposits, it is $Pb.CO^{3}$ from change of Galena to $PbSO^{4}$ and then by $CaCO^{3}$ to $PbCO^{3}$ and $CaSO^{4}$; e. g., Leadville, where are carbonates with hydrated iron oxide.

c. Zinc blende becomes smithsonite in like circumstances.

d. Gold quartz veins become cellular quartz stained red by iron oxide, with free gold in strings and grains.

8. Veins probably filled by hot alkaline solutions rising from great depths. Facts supporting this theory.

Ore deposits are due to some process of concentration of particles once widely disseminated, either from a mechanical grinding up and concentration, as in placers, or more commonly from chemical solution bringing into cavities particles once scattered. This process is going on under our eyes in case of iron ores; others which need depth as a condition, may go on unseen.

9. Distribution of ore deposits :

a. Ore deposits more frequent in regions cut by eruptives, and so in mountain regions; possibly because their fissures were effects of such disturbances, and conditions favorable for filling were presented by eruptions and their sequelae.

b. Ore deposits more frequent in old crystalline and metamorphic rocks and in other formations of high antiquity, partly because fit conditions for deposit of many ores may be presented by great thickness of cover, needing much time for them to be laid open by denudation; partly, doubtless, because older rocks have been longer exposed to chances for being cut by veins.

Value of Ore Deposits, Etc.

1. The practical value of mineral deposits will depend on several considerations :

a. On amount of mineral in the ore relative to cost of extraction and marketing.

b. Proportion of value in ore to that of rock which must be handled since 3′-4′ must be mined out.

c. Ease and cheapness of exploitation—cost of labor, power, supplies; hardness of rock.

d. Situation with regard to transportation.

e. Cost of beneficiation—nature of ore, simple or complex; convenient smelting facilities; ease of concentration; facility of parting.

f. Demand for human use.

g. Fallacy of supposing that lodes grow richer in depth; change of character in depth.

h. Need of careful and fair sampling in forming an estimate of value.

2. Common ore associations :

a. Gold with iron and copper sulphides.

b. Manganese with Fe., franklinite, etc.
c. Nickel with Co. and As., common.
d. As. with Sb. or replacing it. Pyrargyrite, etc.
e. AgS. with Pb S and ZnS. being analogous.
f. PbS. with ZnS.
g. Tin with tungsten, pyrite, copper, etc.
h. Pt. with Ir. palladium, rhodium, osmium.
i. Pyrite with chalcopyrite.

Zonal Distribution of U. S. Ores.

1. In a general way this zonal distribution probably holds good, if not pushed too far, and follows in a general way lines of successive uplift and disturbance.

a. Coast range, Hg. chrome, etc.
b. West foot-hills of Sierras, copper.
c. West slope of Sierras, gold.
d. East base of Sierras, Au. and Ag., little base stuff.
e. Central Mexico, Arizona, C. Nevada, Idaho, Ag. base.
f. New Mo., Utah at base of Wahsatch Mts, W. Montana, argentiferous galena.
g. E. new Mo., C. Colorado, Ag. and Au. complicated.
h. Appalachians, Au., Cu., Fe., etc.

Iron.

Ferrum, Fe.

1. Chief ores—Magnetite, Hematite, Limonite, Siderite, Spherosiderite, Black-band and Franklinite.

2. Mode of occurrence, in beds, sometimes stöcke :

a. In Archaean. where it is metamorphic.
b. In Lower Silurian, mostly limonite.
c. In Upper Silurian, in Clinton group.

d. In Carboniferous, as clay iron and black band.

e. Associated with Triassic coal.

f. In Middle Lias, Cleveland Dist., Yorkshire, 10′–20′ of bluish, oolitic, clay carbonate 30 to 35 per. cent. yields $\frac{1}{6}$ of the world's iron.

g. Some clay iron in Cret. coal beds, and as bog iron, modern.

3. United States localities:

a. In Archaean of (1) N. E. New York, Canada, and N. Jersey, magnetite, etc.; (2) Upper Michigan, hematite, some magnetite; (3) Missouri, at Iron Mt., hematite; (4) Mitchell Co., N. C., 3 miles from Tenn. an immense bed of Fe^3O^4, 200′–800′ free of S and P. (Kerr, N. C. Rep., 1875, p. 263.)

b. In Lower Silurian (Potsdam, Knox Gr.) E. Tenn., as limonite; also in valley of Va. extensive beds of ores 40–52 per cent. Calciferous, limonite in Lehigh Co., Pa., very important ranges; also, probably, the ore belts of Adams and York Co.'s; also, stöcke in valley of Virginia. Ore beds, limonite, E. of Hudson River in Dutchess, and Columbia Co.'s, related to limestone and talc slate, mica slate, etc.

c. Clinton group in Central New York, oolitic; in Pa. and East Tenn.; in Ala. 10′–20′ yields 40–55 per cent. (Hunt, E. and M. J., March 3, '83.)

d. At many points in coal measures (clay iron, black band.)

4. Importance of proximity to fuel and fluxes; or, for transportation, of high per cent of iron. Also freedom from S. rendering Fe, red-short, and from P. of which more than $\frac{1}{1000}$ causes cold-shortness. Basic process.

5. Sketch of mode of reduction, fuels and fluxes.

6. Steel, an intermediate product between cast iron and wrought iron, contains from .5 to 1.32 per cent. of carbon; will temper, and is malleable both hot and cold unless tempered. How made: (By cementation; by Bessemer process; by fusion of pig and dilution with wrought iron in a regenerative furnace.)

7. Uses of iron and steel:

Railroad bars, bridges, pillars for buildings, tools, etc., stoves, furnaces, and boilers, machines, pipes for water, oil, etc., tanks, car wheels, wire for fences and telegraphs, ship building.

8. Production of world, 1882, 20,656,184 L. and M. ton.
" Gt. Britain, " 8,493,287 L. ton.
" Unit. States, " 4,623,323 L. ton.
" Germany, " 2,945,007 M. ton.

Pyrite.

1. Qualities adapting for acid making:

a. High per cent. of S. Highest 53.3, worth $14.00 per ton.

b. Freedom from As. Sb. and Pb.

c. Readiness to part with S. on burning.

d. Neither soft, nor too coarse or too fine.

e. Difficult of fusion ∴ free from Pb.

f. Not liable to decrepitate in burning.

g. A good per cent. of Cu. is also important. This is either paid for, or burned pyrite returned to seller.

2. For copperas making, it is first heated in retorts to drive off from 12 to 17 per cent. of S. which is collected; or else roasted in heaps; residue weathered to $FeSO^4$ and leached.

3. American localities of large deposits at Stafford, Vt.; Milan, Coos Co., N. H.; and at Capelton, Garthby, and several other places in Canadian Huronian.

4. European localities:

a. Rio Tinto, in Huelva, Andalusia, in S. Spain in green metamorphic talcose and mica schists, passing into clay slate. Here it occurs in vast beds or lenticular masses averaging 250′, but sometimes nearly 1000′. S. 49 to 50 per cent., Cu. 3 to 4 per cent: was wrought by ancient Romans (V. Cotta 2d, p. 452.)

b. At Goslar in Hartz Mts. in Dev. shales and limestone in great beds or stocks of cupriferous pyrite 350′ thick, and at least 1800′ long. Has very subordinate amounts of 13 other metals. (V. Cotta, 2d, p. 103.)

c. At Agordo, Tyrolese Alps, and at Fahlun, Sweden, are found similar vast stocks, the first in Pre-carb. slates, the second in mica schist, probably Huronian. (V. Cotta 2d, pp. 334 and 525.)

Gold.

1. Found native alloyed with silver and some other metals. Sparingly in a few localities, compounded with tellurium.

2. *a.* Occurs normally in veins in schists and granite, with quartz as its usual gangue, and pyrite, chalcopyrite and mispickel for its common associates; e. g., Appalachians, Sierra Nevada.

b. Very commonly in placers, often covered with trap rock; e. g., California at foot of Sierras, and in Australia and Ural Mts.

3. Chief gold regions:

a. On east slope of Appalachians from Georgia to Atlantic coast of Nova Scotia, and in Quebec S. of St. Lawrence River.

b. In Black Hills of Dakota.

c. In Colorado, mostly in Gilpin, Clear Creek and Boulder counties.

d. With silver in Comstock vein and Eureka district of Nevada.

e. Most largely in California and Oregon along Sierras.

f. In placers in Colombia, Venezuela and Guiana, S. America.

g. In Eastern Australia, Tasmania and New Zealand.

h. In Africa, along both coasts.

i. In Ural Mts. of Russia, and in Hungary along Carpathians.

4. Mode of extraction (1) by hydraulic methods in placers; (2) by stamping the rock and catching gold with mercury on plates of copper; (3) stamping, concentrating, roasting to expel sulphur, treating with Cl., leaching out Ag^2Cl. and precipitating with copperas.

5. Used for coin and ornaments.

6. Amount produced in 1883 = 141½ metric tons.

United States,	$45\frac{15}{100}$	"	"
Australia,	$39\frac{9}{10}$	"	"
Russia, Ural Mts.,	$35\frac{9}{10}$	"	"

Value of product of 1883 = $94,027,901.

7. Value of Gold:

Per oz. Troy,	$20.6718.
" lb. "	248.06.
" oz. avoirdupois,	18.84⅛.
" lb. "	301.46.
" kilogramme,	614.628.

Silver.

argentum, Ag.

1. Mode of occurrence, mineralogical.

a. Native in small amounts; Freyberg; Silver King; L. Superior.

b. Commonly as sulphides, and with Sb or As.

Argentite = $Ag.^2S$, 87 per cent. silver.

Stephanite = $6Ag^2S + Sb^2S^3$, 69 per cent. silver.

Pyrargyrite, *i. e.*, Ruby silver, = $3Ag^2S + Sb^2S$ = 59 per cent. Ag.

Proustite = $3Ag^2S + As^2S^3$ = 65 per cent. Ag.

Fahlerz or grey copper = $Ca^8Sb^2S^7$,Cu partly replaced by Ag.

c. Sometimes as chlorid, kerargyrite, *i. e.*, horn silver, in upper part of veins, or where salt springs occur; Ag. 75 per cent.

d. Very largely in argentiferous galena, or with Zn.S.; e. g., Leadville, Col.; Eureka, Nev.; Horn Silver mine, Utah; Georgetown, Col.

2. Geological position :

a. In veins in older granitoid and cryst. Schists; e. g., Georgetown. Col.; Reese R., Nev.; Silver Islet, Lake Sup.; Kongsberg, Norway; and Freiberg, Saxony.

b. In veins encased in or associated with older type of volcanics; e. g., Comstock; Batopilas in Mexico.

c. Impregnations in Triassic S.S., Silver Reef of S. Utah; or in joints and strata of lime and shale of Devonian Age, White Pine, Nev.

d. Associated with lead in veins or chambers of several ages; e. g., San Juan veins, Archaean; Leadville, Carboniferous.

e. Associated with native Cu. in Huronian, Lake Sup.

3. Chief supplies at present, from Rocky Mt. region and extension :

a. From Leadville, Georgetown, Caribou, and San Juan, Col.

b. From several points in Arizona, Tombstone, etc., being second in amount.

c. From Nevada, Comstock, Eureka, Reese River.

d. From Utah, near Salt Lake and in S. W. part. Also California, Montana, N. Mexico.

4. Foreign sources: Mexico, Chili, Bolivia, Germany, Austro-Hungary, Spain, etc.

5. Mode of reduction, slight sketch.

6. Production 1882 = $46,800,000 = $39,900,000 at $1.11.

Colorado,	1st,	$16,500,000	Montana,	5th,	$4,370,000
Arizona.	2d,	7,500,000	Idaho,	6th,	2,000,000
Utah,	3d,	6,800,000	New Mex.,	7th,	1,800,000
Nevada,	4th,	6,750,000			

◆

Copper.

Cuprum. Cu.

1. Mode of occurrence, mineralogical:

a. Native in amygdaloids, conglomerates and veins.

b. Chalcopyrite = $\mathrm{Cu.Fe.S^2}$ = 34 per cent. Cu., and in pyrite, e. g., Spain.

c. Chalcocite, copper glance, $\mathrm{Cu^2S}$. with other Cu. ores.

d. Malachite, $\mathrm{CuCO^3}$, valuable also for ornament.

2. Geological occurrenee:

a. In veins cutting Archaean or Palaeozoic; e. g., Keweenaw Co., Mich.; Ore Knob, N. C.; Cornwall. Same associated with gold, Gilpin Co., Col.

b. Interstratified veins or beds in Archaean and Canadian; e. g., Ducktown. Tenn.; many points in East Canada.

c. Mass deposits, Copperopolis, Cal.; and in pyrite, Spain.

d. Impregnating as metal beds of amygdaloid and conglomerate, Lake Superior.

e. Impregnating bituminous shales, Kupfer Schiefer, Germ.

3. Important localities, U. S.:

a. Lake Superior region greatest, Calumet and Hecla, Quincy, etc.

b. Arizona, a large producer, Copper Queen, etc.

c. Montana, at Butte City, great.

d. Copperopolis, Calaveras Co., Cal., small product.

2º In quartz vein cutting in cambrian cong. Savin Hill sel. Boston Mass – a trace – J.B.W.

Schuyler Mine, Belleville, N. J. Triassic, contains up to 1719 – associated w. injected trap sheets –

e. Along west slope of Alleghanies (Ducktown, Tenn.; Ore Knob, N. C.)

f. Promise in Mo., Wy., etc.

4. Foreign production:

a. Southern Spain, with pyrite, in 1881, 23,478 M.T.

b. Germany, Mansfeld from Kupfer, in 1880, 22½ M. T. Ag., 9800 M. T. Cu. With pyrite, etc., in 1882 = 20,011 M.T.

c. Great Britain; Cornwall, Devon, Anglesea.

d. S. Australia and N. S. Wales, = 11,000 T.

5. American product, 1883, = 52,916 Met. tons.

Chief producers, Lake Superior.
Arizona, Copper Q.; Globe Dist.; Clifton Dist.
Montana, near Butte City.
Colorado, from gold, etc.

6. Uses: vessels and utensils, wire, galvanic batteries, sheathing ships, alloys as brass and bronze, sulphates, arsenates, chromates, and acetates.

Lead.

1. References: Geol. Wis., 2, 689; Illinois, 1, 155, etc.; Missouri Old Rep., and New 1, 384.

2. Chief ore, galenite with cerussite and anglesite resulting from decomposition.

3. Geological occurrence:

a'. Chiefly in form of stock deposits, whether chambers, gash veins, or contact; limestone associates.

b'. Impregnating sandstones; e. g., German Bunter in Rhine provinces, sometimes 250' thick (Credner.)

c'. In veins with silver; San Juan, and in English and Welsh Carboniferous.

4. Chief production:

a'. In western territories as auxiliary of Ag., Leadville, Eureka, Horn Silver, etc., Georgetown.

b′. In Missouri, S. E. Co.'s, L. Silurian; central Co.'s, Sub. Carb.; chiefly S W. Co.'s and adjacent Kan. at Joplin.

c′. In Ill., Wis., and Iowa, and Wythe Co., Va.

d′. In Germany, Spain, and England chiefly; some from Greece, Austria, Italy, and Russia.

5. Product:

United States,	1883	= 145,289 T.	= 131,805	M. T.
Germany,	1882,		92,525	"
Spain,	1883,		123,000	"
England,	1882,		51,136	"

6. Uses of lead:

a. Sheets for roofing; lining chambers for H^2SO^4 and pans for concentration; lining tea chests, etc.

b. Tin-foil for various linings.

c. Pipes for water and gas, etc.

d. Alloys, shot, type metals, stereotype, soft solder.

e. Compounds, white lead $PbCO^3$ and $PbCrO^3$ pigments; litharge for glass; red lead, pigment and for glass; acetate or sugar of lead.

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Zinc.

1. Mode of occurrence, mineralogical:

a. Sphalerite, blende, ZnS.

b. Smithsonite, $ZnCO^3$

c. Calamine, galmei, $ZnSiO^3$.

d. Zincite, red oxide, ZnO.

e. Franklinite, Fe, Mn, and Zn, yielding Zn, and spiegel iron.

2. Geological occurrence:

a. Chiefly in stock deposits associated with Pb. and calcite.

b. In true veins with silver, etc., Georgetown, Col.

c. Contact deposits of Calamine filling tray-like cavities in dolomite of Muschelkalk, Upper Silesia (Credner.)

3. United States localities:

a. Franklin, Essex Co., N. J., in limestone.

b. Lehigh Co., Pa., near Bethlehem, Lower Sil. Mag. Lime.

c. Galena district.

d. Lead and zinc region of S.W. Mo., Sub. Carb., near Joplin and Granby. The last thought to furnish ⅔ our product.

4. Production :

Germany, in Upper Silesia, etc.,	1882 =	108,545	M. T.
Belgium, in Liege district.	1881	93,811	"
England, with lead,	1882	16,389	"

5. United States product, 1883, 29,747 M. T.
World's " " 278,000 M. T.

6. Uses : (1) roofing, cornices, water-spouts, galvanizing iron, galvanic batteries, galv. fence wire. (2) Alloys, German silver, hard solder, mosaic gold. (3) Compounds, zinc white for paint; $ZnSO^4$, mordants and medicine; ZnCl, disinfectant and preserving timber, burnetizing.

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Quicksilver.

1. See U. S. Rep. on Min. Resources, 1867, p. 170, and 1876, p. 18. V. Cotta, Erzlagerstätten, p. 67, and 2d part, p. 455. Whitney Geol. Rep. of Cal., Vol. 1. For Idria, Eng. and Min. Jour., Dec. 24, '81, p. 417; and Oct. 7, '82.

2. Occurs usually as cinnabar, Hg.S., reduced by roasting with Fe or lime; also native.

3. Geological occurrence, as an impregnation of porous and much-disturbed strata, of ages ranging from Silurian to Tertiary or Cretaceous?

4. Topographical occurrence :

a. In Coast Range of Cal. in 8 Co.'s from Trinity on the north to Santa Clara and Fresno on the south, in metamorphics of Cret. or Tertiary age; impregnating inclined strata of sandstones as in Trinity Co., or jaspery slates as at New Almaden associated with serpentine; or in talcose and argillaceous slates.

b. Almaden, Spain, province Ciudad Real, N. E. of Cordova, on a branch of the Gaudiana, in immense beds 67′ wide, vein-stone quartz enclosed by beds of carbonaceous slates and quartzite, etc. of Silurian age. Mine 1050′ deep in 1851. Worked since and before Roman occupation.

c. Idria, Austria, in Carniola, N. of Adriatic, in bituminous schists and dolomites, or in cross fissures of limestone. Grows richer in depth; 950′ deep; worked since 1490. Product averages 427 tons; ore 1.6 per cent. Rocks of Triassic age.

d. Spain produces some from Asturias in the north.

5. Used : *a.* For extracting gold and silver; *b.* making barometers, thermometers and other instruments; *c.* for mirrors; *d.* for medicine, calomel; *e.* for pigment as vermilion and $HgCl^2$ for preserving wood; *f.* for fulminate in percussion caps.

6. Production : Spain, 1881 = 1812 net tons.
U. S., 1883 1787¼ net tons.
World, 1880 4420 net tons.

Platinum.

1. Found always native alloyed with Iron, Iridium, Osmium, etc., and always in placers.

2. Chief supplies are from east slope of Ural mountains, Russia. Some also obtained from Borneo, and from Colombia where it was first discovered.

Small amounts reported from California, Oregon, and from Wood River, Idaho,

3. Uses for chemical apparatus, Sulphuric acid stills and worms.

4. Product: Urals, 1882 = 6798 lbs. avoirdupois.
Borneo, " 500 " "
United States, " 14 " "

Tin.

1. Ores Cassiterite or Tin stone, SnO^2, called stream tin when occurring in placers.

2. Occurs in veins in granite, gneiss and mica slate, associated with many other minerals, notably Wolfram; also largely in placers.

3. Chief regions are (*a*) Cornwall in E. and W. veins and in placers.

b. Straits of Malaeca in islands of Banca and Billiton, placers.

c. Australia, in South Queensland and New South Wales in veins in granite and in extensive placers.

d. In United States, in Black Hills of Dakota, veins in coarse granite; also in Clay Co., Alabama. Both recent discoveries.

4. Uses: *a.* To tin iron plate and iron and copper utensils; *b.* as tin-foil with lead for wrapping delicate articles; *c.* with mercury for silvering mirrors; *d.* in alloys, as pewter, bronze, bell metal, britannia, solder, etc.; *e.* oxide called tin-putty used for polishing marble and in enamels; *f.* chlorides used as mordants in dyeing and calico printing.

5. Amount produced:

Great Britain,	1882,	8158	tons.
Australia,	1883,	8125	"
Malacca,		8000	"
Other regions,		1136	" mostly Bolivia.

Coal.

1. Varieties:

a. Anthracite, sp. gr. 1.5–1.8, hard, lustrous, little volatile, blue flame.

b. Semi-anthracite, sp. gr. 1.4–1.6, 5–12 per cent. volatile, kindles easily, flame.

c. Semi-bituminous, sp. gr. 1.35–1.45, 12–20 per cent. volatile, flame, may cake.

d. Bituminous, sp. gr. 1.35–1.25, 20–50 per cent. volatile, flame long.

(1) Caking, agglutinates.

(2) Dry-burning, block, splint, cherry. non-agglutinating.

(3) Cannel or parrot, structureless, conchoid, often ashy.

e. Brown coal or lignite, brown powder, water, crumbles.

f. Peat, brown, of recent swamp origin.

2. Analysis:

	1	2	3	4	5	6	7	8	9	10	11	12
O.	71.48	70.46	70.42	78.98	81.27							
H.	5.47	5.69	6.50	5.92	5.66							
N.	1.26	1.82	1.65	1.58	1.66							
S.	0.57	0.91	1.34	0.56	0.98	0.23				0.85		0.24
O.	16.07	18.77	6.89	11.50	7.08							
Ash.	5.15	2.35	13.20	1.45	3.35	1.11	6 13	7.16	16.00	10.77	17.68	3.00
Water.	7.20	8.50	2.60	2.47	0.90	0.76						
Sp. Gr.	1.262	1.298	1.43	1.26	1.31		1.55	1.4	1.79	1.32		1.21
FixedC.	57.55	56.85	44.0	64.25	66.85	79.26	90.20	82.86	77.0	73.11	47.22	47.00
Volatile	30.10	32.20	40.20	31.83	28.90	18.65	2.52	9.98	3.0	15.27	52.78	50.00

1. Straitsville, Ohio; 2. Jackson Co., Ohio; 3. Flint Ridge, Ohio, cannel; 4. Briar Hill, block; 5. Youghiogheny, Pa., coking; 6. New River, Va., semi-bituminous, coking; 7. Beaver Meadow, Pa., hard anthracite; 8. Average 11 semi-anthracites, Pa.; 9. Rhode Island anthracite; 10. Blossburg, semi-bituminous; 11. Near Franklin, Pa., cannel; 12. Owsley Co., Ky., cannel.

3. Mode of occurrence and associations:

a. Usually clay bed below, underclay. Above, clay, sandstones, limestones, etc. Usually not more than $\frac{1}{60}$ coal; (Ohio, 1′ to 16′; Saarbruck, 1′ to 26′; Westphalia, 1′ to 32′.)

b. In same coal basin usually a tolerable amount of continuity in chief accompanying strata especially limestone; key rocks.

c. Thick seams. Mammoth 100′–114′; Pictou, N. S., 38′, etc. They usually have clay partings; union of seams.

d. Number of seams: Wales, 100; Nova Scotia, 81; Ohio, 12. Many thin. New R. Va. in 1200′ has 67′ coal, in 16 seams, 11 good. Three feet of coal workable.

e. Structure often laminated and with charcoal layers.

4. Origin: in vegetable decomposition, probably smothered. Proofs: Lycopod spores, $C^{12}H^{10}O^{10}$.

a. Results CO^2, C^2H, H_2O, C, and coaly hydro-carbons.

b. Elimination of these now going on—dangers.

c. Loss by decomposition 60–75 per cent. of weight.

d. Thickness of resultant beds $\frac{1}{5}$ to $\frac{1}{8}$ of vegetable matter.

5. Impurities in coal:

a. Ash—usually averages 2–6 per cent. or more. Average of

154 Ohio coals 4.89 per cent. Composition; Silica, averages nearly 48.9, Al^2O^3 36.5; Fe^2O^3 8.06, from six Ohio coal ashes. Some alkalis, lime. etc.

b. Sulphur—from 0.11 of 1 per cent. up, partly as pyrite, partly resin. Injurious. Eliminated very unequally in coking. (Geol. Ohio 1870, p. 411.)

c. Phosphorus—occasional—deleterious.

d. Water and nitrogen, waste, latent heat.

e. Origin of impurities.

6 Calorific power and intensity. analysis 1 above.

$$(H - \tfrac{1}{8}O) \times 34462 + C \times 8080 - \tfrac{9}{8}O \times 537 = C.\ P.$$

$$\begin{array}{rll} H \times 34462 & 5..7 - 2.01 = 3.46 \times 34462 & = 1192.3852 \\ C \times 8080 & 71.48 \times 8080 & = 5785.584 \\ H^2O \times 537 & 16{,}07 + 2.01 = 18.08 \times 537 & \quad 97.0896 \\ \hline & & 6870.8796 \end{array}$$

Real Cal. power little exceeds that due to C. (Rogers.)

7. Geological occurrence of coal:

a. Chiefly in Coal Measures; some in Sub-carb.

b. In Trias of Va. and N. C.; also in Lower Oolite of G. B.

c. Upper Cretaceous of West U. S. Of great value and extent.

d. European Tertiary, mostly miocene. Brown coal.

e. Peat in modern marshes.

8. Distribution Topographic:

a. New Brunswick, etc.,	18,000 Sq. M.
b. Rhode Island,	500.
c. Appalachian,	59,000.
d. Central Michigan area,	6,700.
e. Illinois area,	47,138.
f. Western area,	78,430.
g. Virginia, Carb. and N. C. areas, Triassic,	495.
h. Cretaceous coals of Col.,	35,000.
i. " " Wy.,	20,000.
j. Cal., Washington, Montana, Dakota,	100,000. (?)
a'. Australia,	24,840.
b'. Great Britain,	11,800.
c'. Spain (Asturias),	3,501.

d'. Russia,	30,000.
e'. France,	2,086.
f'. Germany (Westphalia, Bohemia),	1,770.
g'. Belgium,	518.
h'. Japan, Tertiary,	5,000.
i'. China (mostly Trias and Lias), rich,	4,000,000. (?)
j'. India, Permian and Trias,	2,004.
k'. Siberia, Carb., Jurassic, Tertiary.	

9. Uses, and qualities fitting for use:

(1) For domestic fuel; (2) for steam generation on land; (3) for steam generation, marine; (4) for blacksmithing; (5) for coking; (6) for smelting, raw; (7) for gas making.

(1) For all uses in general a coal should be:

a. Free from S. and P.; (*b.*) reasonably free from ash, especially such as tends to clinker from presence of Fe.,$CaCO^3$ and alkalis. (*c.*) Firm enough to bear transportation without undue breakage.

(2) For domestic use a coal should be of (*a*) good calorific power; (*b*) non agglutinating; (*c*) not smoky nor of light ash; (*d*) capable of holding mild and steady combustion with feeble draft.

(3) For steam generation is needed—(*a*) high evaporative power; (*b*) easy kindling and free combustion, from volatile constituents being free gases; (*c*) no tendency to agglutinate, but rather to split somewhat in burning, giving large surfaces.

(4) For marine purposes is needed with above qualities, susceptibility of compact stowage, due partly to sp.gr., partly to form of breakage, cubical breakage being best.

Semi-anthracites seem best according to Rogers, semi-bituminous ac. to Johnson. (Geol. Rep. of Pa., Vol. 2, p. 997 and 1000.)

(5) For blacksmithing, a pure, agglutinating coal.

(6) Coking needs agglutinating coal with high per cent. of carbon, little ash, and which will yield a large amount of hard, strong, cellular coke free from S. and P. Essential qualities of coke for blast furnace use are—(*a*) hardness of body to resist solution by CO^2 in upper region; (*b*) well developod cell structure, for calorific energy, relative work of coke and anthracite being as 800': 500: (*c*) Purity, *i. e.*, freedom from ash, S. and P.; (*d*) Uniformity of quality, for regularity of work; (*e*) Freedom from water.

(7) For smelting is needed a strong. free-burning coal, with little ash, and little tendency to split in burning.

(8) Gas making needs abundant yield of volatile ccnstituents and little separable S. or P. A solid residue of coke highly desirable. Cannel very gaseous but yields little and crumbling coke.

10. Production of Coal:

Great Britain,	1881,	154,184,300	Tons	L.
Germany,	"	48,688,161	"	M.
" Lignite,	"	12,852,324	"	M.
Penn., anthracite,	1882.	29,316.387	"	L.
U. S., bituminous,	"	57,963,038	"	L.
Austria, coal,	1881,	6,343,316	"	M.
" lignite,	"	8,961,498	"	M.

11. Peat is widely distributed over the Northern States, Canada, Alaska, Ireland, Scotland, England, Holland, and Germany.

Holland is said to raise 40,000,000 tons a year.

Objections, its odor, and the high amount of water, 25 per cent.

Prepared by cutting and drying, or pulping and pressing. Might be bettered by charring.

OTHER SOURCES OF HEAT AND LIGHT.

1. Bituminous shales:

a. Utica shale, probably bituminous.

b. Marcellus and Genesee 50′–100′ thick, are bituminous, sometimes even inflammable; mistaken for coal bearing—occasionally a source of gas springs.

c. Huron shale of Ohio = Genesee, etc., 200′—350′ contains (Newberry) 10–25 per cent. combustible matter and thin sheets of asphalt. From 10–20 gallons oil per ton can be distilled from it, springs of oil and gas constantly accompany the outcrop.

The important gas wells along Lake Erie shore from near Cleveland to Fredonia are probably from this horizon, and great numbers of gas wells have been obtained from it in Ohio.

d. Cleveland black shale contains from 10–20 per cent of volatile matter and is the source of small oil wells at Mecca and

Grafton, Ohio, and of gas wells here and at Liverpool, Columbiana Co., Ohio.

e. The oil measures of Pa., are an abundant source of gas of high heating and considerable lighting power. Most of these sources have a limit of life, though many furnish an enormous quantity of gas for considerable periods; e. g., Titusville well. These gases are chiefly hydrocarbons with some H. and CO^2.

For value as fuel see Rep. L. pp. 146–160, 2d Geol. Rep. Pa.

PETROLEUM.

1. References, 2d Geol. Rep. of Pa., Vols. I, I^3, I^4 and R: Mineral Resources of U. S. 1882: American Cyclopedia.

2. Fluid hydro-carbons, varying composition—in Pa. and N. Y.

a. Light gravity 48° to 36° B—amber, green, dark brown.

b. Lubricating oil 35° to 27° B.

c. Associated with salt water and gaseous hydro-carbons.

d. Occurs in loose or pebbly sand rock, imprisoned by shales above and below.

e. At Bradford, Pa., loosely cemented fine sand 45′ thick, very uniform over 110 square miles. Few dry holes—wells 1200′ to 2000′ deep.

f. Venango and Butler Co.'s, Pa., in a triple group of sands often pebbly, separated by shales. Group 350′ thick. Hence 1st, 2d and 3d sands—sand rock in belts and variable, many dry holes. Depth 400′ to 1800′.

3. Geologic horizons, and regions:

a. Corniferous—wells of western Ontario.

b. Chemung—wells of S. W. New York and of Penn.

c. Carboniferous, West. Va. and Ohio, often lubricating.

d. Tertiary—Southern California; Los Angeles and Venturas Co.'s.

e. Bakoo on Caspian, area 1260 miles. Increasing product.

f. Rangoon and islands W. of Burmah. Long known.

4. Mode of boring, casing, tubing and torpedoes.

See Pa. Geol. Rep. I^3, and Min. Res. of U. S. 1882.

5. Production of Pa. and N. Y. 1882 = 31,446,000 bbls of 42 galls.

6. Ozocerite—Mineral Wax or Paraffine :

Found in Southern Utah in 1877.

Occurs in beds of coal or bituminous sandstone at Slanik in Moldavia, and at foot of Carpathians. Used for candles.

See Mineral Resources of U. S., 1882, p. 609; and Eng. and Min. Journal, Jan. 12, '84, p. 20.

Fictile and Refractory Materials.

1. Infusorial earths like those of Richmond, Va., Monterey, Cal., largely used for polishing powder, and in dynamite, may be used mixed with a paste of fire clay and lime, for making a very light and refractory brick, only $\frac{1}{6}$ the weight of ordinary brick, for lining safes, and about exposed parts of ships.

2. Meerschaum, a hydrous silicate of Mg., occurring among serpentinous rocks in Greece and Asia Minor, used chiefly for pipes, but the coarser parts used for porcelain.

3. Clays are hydrous silicates of alumina, mixed with variable portions of sand and impurities. They originate from the decomposition of rocks holding feldspar, chiefly orthoclase and oligoclase, the materials being usually washed down into low grounds and there deposited, the finest and purest generally farthest from the place of origin.

a. Porcelain clay is a fine, white, plastic clay, found in China, Cornwall, Limoges (France), Dresden (Saxony), and in N. J. Middlesex, etc., Co.'s, and Lawrence Co., Indiana: where found, the basis of a great industry. Prepared by careful washing, removing some injurious substances by acids, and mixing with due proportions of pure sands and other substances.

b. Ordinary pottery or stoneware clay, less pure than first, especially as regards Fe., made into jars, jugs, etc., which owe their grayish or greenish tint to iron silicate.

c. Brick and tile clays used for roofs, floors, drain pipes, etc., are coarse admixtures of Kaolin with much sand, iron and other impurities. The amount of lime should not exceed 2 per cent. from liability to glazing. The iron usually colors the brick red, unless alkalis are present. Found in superficial deposits.

d. Terra Cotta clays are fire clays with proper proportions of iron, and by mixing judiciously afford a variety of tints.

e. Feldspar is a name given in N. J. to an intimate mixture of Kaolinte with about 60 per cent. of white quartz sand; while Kaolin = a glistening, slightly unctuous micaceous sand with a little clay; sand = 60–90 per cent.

f. Fire brick clays. These should be free from alkalis, lime, and iron; of uniform texture; somewhat greasy in feel; unctuous or plastic. Found largely among the under clays of the coal measures, needing long weathering. Also very abundant in the N. J. Cretaceous, which affords the best in the world.

After proper ripening, it is mixed with varying amounts of Feldspar, or well-burnt clay, or coarse sand, moulded and burned for fire brick; retorts for gas-making and zinc-reduction; Glass pots; sewer pipes, and chimney tops.

g. Other uses for clays are (1) for surfaceing wall papers; (2) rich clays used for alum making; (3) for artificial production of Portland cement; (4) and for making clay smoking pipes.

4. Characters of clays:

a. Chemical composition. The nearer to pure Kaolinite the better. With much KO, CaO, and Fe^2O^3 they form fusible silicates. Iron above 2½ per cent. seems even more detrimental than potash.

b. Plasticity, which seems to be promoted by breaking up the crystalline plates and bundles of Kaolinite. Hence weathering and pugging.

c. Tendency to shrink and crack at high temperatures. This varies with amount of Kaolinite; so that for many purposes sand is added to temper the clay, diminishing tendency to shrink and crack.

d. Fusibility—least in Kaolinite, and depends on per cent. of alkalis, alk. earths and iron; partly also on density and fineness of grain, which seem somewhat to promote fusibility.

5. Tests of refractoriness by which the clays in illustrative table and also fire-bricks were classified. N. J. Report for 1880, p. 131–152. Pa. Report M^2, p. 271.

Analyses, Cook's Rep. N. J. Clays 1878.

6. Silica bricks of Germany and France made from sand mixed with 5–10 per cent. of fire-clay.

7. Dinas brick composed of 95–98 per cent. Silica with small amounts of Alumina and a small per cent. of lime. Burned several days, the small amount of lime furnishing cement. Refractory to 4000° F.

8. Graphite—The final stage in metamorphism of vegetation.

a. Occurs usually in nests or strata accompanied by much impurity, in Archaean or other metamorphic rocks. Occasionally, as at Borrowdale, Eng., in veins in trap, or rather interbedded greenstone.

b. Found in Urals and Siberia; at Borrowdale, Eng.; in Bavaria (German product 1881 = 1510 tons); in Austria, product of '81 being 13,379 tons; in Ceylon; near Ticonderoga, N. Y.; near Ottawa, Canada; Stouerbridge, Mass., etc.

c. Uses: (1) For crucibles and melting pots, mixed with ⅓ to ½ fire-clay and pressed in moulds; (2) Pencils, being ground, pressed into blocks and sawn, or pressed to crayon form; (3) Lubrication of machinery; (4) Stove polish and protection of iron.

9. Magnesia—coming into use as a refractory basic lining for Bessemer converters, formed from dolomitic lime mixed with 10 per cent. tar and pressed into forms, eliminating 3 per cent. phosphorus in a slag which may be used as a fertilizer; also pure magnesia, and magnesian silicates are highly refractory; as talc. Asbestus used for steam packing.

10. Firestones—forms of silicious sandstone and quartzite—mostly superseded by fire brick, though used some for forges, hearths, etc.

Building Stones, Etc.

1. Desirable qualities:

a. Durability—dependent on locality, city or country; climatic variability; manner of laying; fineness of grain and homogeneity to resist changes of temperature; closeness of texture to resist moisture and frost; freedom from decomposable ingredients.

b. Strength—how tested—depends on closeness of texture; direction of strain to bed; elasticity, limestone greatest; degree and means of consolidation; hardness and cleavability of grains.

c. Beauty of color—neutral tints, and reddish color; color when weathered.

d. Facility of working—dependent partly on hardness, partly on structure; *i. e.*, on the way in which the materials are arranged and interlocked.

e. Susceptibility to fine finish and polish.

2. Sandstones, variable in comp. and consolidation, strength and durability; widely diffused.

a. Potsdam of Marquette etc., and of Potsdam.
b. Medina, hard and strong.
c. Sub-carb. of Ohio, qualities, building, grindstones.
d. Triassic, Newark and Trenton, N. J., Conn. etc.
e. Ithaca, argillaceous S. S.

3. Limestones—marbles—qualities—in cities using bituminous coal magnesian lime to be avoided.

a. Trenton lime, of Canada and N. Y.
b. Springport and Syracuse, strong but dark.
c. Tully, fit only for rough work—flawy.
d. Niagara of Lockport, often unreliable.
e. Marbles, Rutland, Vt., and Gouverneur, N. Y.
f. Marbles, east and central counties of Tenn.
g. Oolitic lime of Ind. Sub-carb. used for Ind. capitol.

4. Granite class. Take fine polish; very hard; endure fire and extremes of temperature badly. Fine grained best.

a. Granites, gneisses, mica schists, syenites found in primary regions, like N. Eng., north New York, Col., Utah. Buildings and monuments.

b. Porphyries and serpentines, for ornamental stones.

c. Trachytes for building and traps for paving.

5. Slates, cleavable, found in disturbed and strongly compressed regions, used for roofing, tablets, mantels, linings, etc.; found in Pa., N. J., and Vt.; near Keweenaw Bay, N. Mich., of very fine quality, largely used in western cities, etc.

6. Paving stones:

a. Trap in blocks 4″ × 8″ × 9″, tough, splits readily; in N. J.; wears smooth; good for macadamizing.

b. Some granites.

c. Sandstones, as Medina, Potsdam.

7. Flagging materials. (N. J. Rep. 1881.)

a. Slates.

b. Argillaceous sandstones; e. g., Ithaca, North River, Cleveland, partly sawn and partly split.

c. Some thin-bedded limestones; wear smooth.

d. Asphaltum concrete, used also for roadways and roofs. Artificial and from Trinidad, Santa Barbara Co. Cal., etc. Paris obtains a calcareous asphalt from Val. de Travers, Switzerland, which is also imported to U. S. (Min. Rep. of U. S., 1882, p. 605.

8. Mortars and cements; chiefly based on lime or dolomite:

a. Hot or calcitic limes; Springport, etc. Trenton, Clinton.

b. Cool or magnesian; Niagara, many western limes.

c. Hydraulic limes, made from stones containing silica and alumina 20–30 per cent. such that when calcined the silica shall have such ratio to the lime, magnesia, and alumina as to form silicates. Essential constituents are carb. of lime (and magnesia) and silica. When calcined, they produce in water hydrated silicate of CaO, or of $CaO + Mg.O$.

9. Sand for mortar and glass.

BRICK CLAY AND TERRA COTTA.

10. Clays, used for brick, tiles, drain pipes. etc., are variable mixtures of Kaolin, sand, iron, and often organic matters and alkalis.

11. Two general classes recognized (1) ordinary red-burning; (2) calcareous, cream colored

a. (1) In N.J., brick clays consist of about 45 per cent. Kaolin, 20 per cent. or more of sand, 8–10 per cent. iron and alkalis; in Wis. less than 25 per cent, Kaolin, 60 per cent. or more of sand, 9 per cent. iron, etc.; (2) clay giving Milwaukee, cream-colored brick consists of about 20 per cent. Kaolin, 4 per cent. iron, 40 per cent. lime, Mg. and KO, residue sand; burned to incipient fusion.

b. Brick clays should have sufficient plasticity, and be free from stones, especially pebbles of lime.

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Geology and Agriculture.

1. Soils are those unconsolidated surface materials which are capable of supporting vegetation. They are usually darker and more mellow than the subsoil some inches below.

2. The origin of soils is usually in decomposition of the underlying rocks or earths ; or in materials transported and deposited from such. Hence soils are (*a*) indigenous; (*b*) transported.

3. Means of decomposition:

a. Action of CO^2, decomposing silicates of alkalis and dissolving carbonates. Decay of vegetation.

b. Action of moisture on FeS. and $FeCO^3$.

c. Action of temperature changes. as frost.

d. Action of roots of growing plants.

e. In transported soils, wear during transport.

1. Bad definition? Define Then according to origin as in 2.

5. a. [illegible]

7. Brachiopods of Miss. Valley [illegible] illustrated etc.

6. "It is not possible to decide about the fertility of a soil on the strength of a chemical analysis." E. G. Schneider. Am. Jour. Vol. XXXVI. Oct. 88 p. 247.

Relative value of hot and cold hydrochloric analyses. Both stronger than common and of [illegible] acids which move soils in nature.

4. How granites become soils and of what kind; how limestones become soils and of what kind; how slates, etc., become soils and of what kind.

5. Constituents of a good soil:

a. Sand = SiO^2, permeable, warm, stalks of plants.

b. Clay = 2½ times alumina, tenacious, support, burnt.

c. Lime and magnesia: 1st, plant food—lightens clay, makes land firm; 2d, for freshness and permeability.

d. Iron oxide, color, acts beneficially on feeble plants.

e. Potash, food for most plants.

f. Phosphoric acid, food of grain and herb plants.

g. Nitrogen, plant food.

h. Organic matter, affords N; gives color; absorbs moisture. Dominance of certain of these elements causes a soil to be called sandy, clayey or heavy, calcareous, peaty,—qualities of each.

6. Analysis of a first-class soil from N. J. as e. g., from decomposition of a limestone:

	Per Cent.	Lbs. per acre 6 in. deep.	Lbs. withdrawn by 5 years rotation of crops, clover 2, corn, potatoes and wheat each 1. Of this 95 lb. P. in clover, straw, and tops goes back.
Silica,	74.65		
Alumina,	8.73		
Iron Oxide,	4.56		
Magnesia,	.54		
Potash,	.47	8187	581 = 14, rotations.
Lime,	.329	5731	239 = 22, “
Phosphoric Acid,	.16	2787	179 = 15, “
Sulphuric Acid,	.024		
Carbonic Acid,	.061		
Organic Matter,	8.25		
Nitrogen,	.206	3588	

Also of KO. 337 lb. in clover, tops, stalks and straw goes back. Weight of acre 1′ deep = 3,484,000 lbs.

The above is an extreme rotation, other crops taking less, and in good farming, a large part of this goes back. (N. J. Rep. 1879, pp. 107 and 114.

7. Color of soils, cause and effect: Due chiefly to iron and humus; aids sand and lime to make soil warm.

8. Nature of sub-soil:

a. It may aggravate, or remedy defects of soil.

b. May restore to soils elements exhausted by cropping.

c. May by its geologic structure facilitate or retard the drainage of flat tracts.

d. May afford wells of fresh, pure water.

9. Geological means afforded for ameliorating unkindly soils or restoring exhausted ones.

a. Use of muck: to improve color and texture; to add organic matter and N.; to increase power of absorbing moisture; to furnish solvents for KO, P^2O^5 and $CaCo^3$.

b. Use of clay and lime on sandy soils; and of lime on clays and turfy soils to improve texture, add CaO, and correct acidity.

c. Use of calc. marls to add CaO, and make soil friable.

d. Use of green sand marl to add P., K. and CaO. Found in N. J. in Cretaceous; also in England. See N. J. Rep. 1868, p. 453.

e. Use of gypsum; found in Salina Gr., Sub-carb., Trias of Texas; and under salt beds.

f. Apatite and other phosphates; found in Laurentian of Canada from Kingston, N. E. to Ottawa Co. Best worth $30.00 per ton, averaging about $20.00 to $22.00; also in great quantities in S. C. Post Plioeene.

See on soils, etc., Mo. 1st and 2d Rep.'s, p. 142–153; N. J. Rep. 1879. pp. 107–120; N. C. Rep. 1875, pp. 162–217; N. J. Rep. 1868, pp. 378–500; Ohio Rep. 1870, pp. 361, 366, 372, and p. 452–459; N. Y. Nat. Hist., Agriculture, Vol. I.

Geology and Health.

The two great requisites for health are pure air and pure water, the first dependent largely on good drainage and sewerage, the second mainly on pure wells and springs.

Water supply [illegible]

1. Need of drainage:

a. To remove surplus water which might breed malarious emanations.

b. To remove waste and decaying fluid matter from vicinity of residences and to prevent contamination of drinking waters.

c. To reclaim swamps that would breed disease.

2. Geological factors in drainage:

a. Slope and outlet to facilitate removal and disposal of injurious fluids.

b. Nature of underlying earth or rock as clayey, sandy, fissured or compact rock.

c. Need of care in sandy and fissured rocks to guard against contamination of wells, etc.

d. For reclamation of districts often the removal of geological barriers and obstructions, e. g., Montezuma marsh over 30,000 acres caused by Jack's reef; Great Meadows, Warren Co., N. J., 5500 acres reclaimed by cutting down a drift barrier.

SPRINGS AND WELLS.

3. These are sources of water arising from the under-ground circulation of the water that penetrates the earth, often to great depths, from rain and snow.

Springs may issue to the surface either (*a*) by simply descending along an impervious stratum to a point of outflow.

b. By hydrostatic pressure along joints, faults, or other fissures.

c. As outlets of streams in caves; e. g., Springport, North Co.'s of Ala., from S. Carb., Huntsville.

4. From various causes also, most districts have a water-level, *i. e.*, one below which they are water soaked; and wells sunk to this obtain a supply, subject only to the varying dryness of the seasons.

5. Driven wells are practicable in valleys filled with alternating layers of clay and gravel, and where they have a dense cover of

clay are often quite reliable; sometimes overflow; e. g., Groton, etc. Cause of this overflow.

6. Artesian wells, often of great depth, derive their supplies from higher ground at long distances, the water being confined beneath an impervious stratum, and rising by hydrostatic pressure, when this is penetrated. Their possibility conditioned by the larger geological structure of the region; e. g., Louisville, Ky., 1086′; Grenelle, Paris, 2000′; London, Algeria, Western Plains, Charleston, S. C., 1970′; N. J.

7. Differences in water of wells and springs:

Hard water, with (Ca. and Mg.) (CO^3, H^2SO^4, and Cl.)

Soft water, little mineral, and that alkaline salts.

Water containing organic impurities, especially from decaying animal matter, dangerous.

Sources and effects of these several impurities: Silicious rocks furnish least of inorganic impurities and calcareous most. Geol. of Wis., Vol. 2, p. 149, and Vol. 4, p. 57; N. J. Rep. 1876, pp. 16–70; N. J. Rep. 1882, pp. 96–174.

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Valuable Technical Materials.

1. Salt, mode of occurrence and origin:

a. Found usually in beds, associated with beds of gypsum, and covered with clay rocks and marls, and often stained more or less with iron.

Origin probably from the desiccation of salt lakes, or sea borders cut off from main body by bars so as ever and again to admit new supplies. Of these gypsum or anhydrite as least soluble, first is deposited, then if evaporation continues, salt, and finally sulphates and chlorids of Mg. etc. deposit, or remain as a mother liquor. (Credner, p. 291–294.)

b. Geologic and Topographic occurrence:

In U. Silurian as at Syracuse and Goderich, Canada.

In Sub-Carboniferous, Michigan, especially Saginaw.
Carboniferous, Kanawha Va., and adjacent Ohio.
Upper Permian, Stassfurt, Prussia.
Triassic, Cheshire, Eng.; Wurtemberg; Vic and Dieuze, France.
Cretaceous? Petite Anse, La. (Min. Res. of U. S., p. 554.)
Tertiary, Wieliczka, Poland, etc.
Some of these form brine deposits; e. g., first three.
Others, salt pools and marshes which abound in Nevada.
Others, solid in immense beds of greater or less purity.

c. Very numerous uses: domestic and antiseptic; soda-making; source of Cl. and H,Cl. and sal-ammoniac; chloridizing agent in metallurgy; glazing pottery and earthenware; agricultural, etc.

2. Nitre, both potash and soda, found largely as efflorescences in certain hot and dry regions; the first in India, Egypt, Persia and Algeria, the second most noted in Central Asia and on some S. American pampas.

3. Borax occurs as boracic acid and as borate of soda. The hot lagoons of Tuscany produce important amounts of first; also found in a number of California lakes. The second is produced in large quantities in San Bernardino Co., Cal; Teel Lake Marsh, Esmeralda Co., Nev.; Fish Lake Marsh, Nev.; and Columbus Marsh, Nev., not far north of Mono Lake.

4. Sulphur, found in volcanic regions as Sicily, Lipari Islands, Jamaica, Black Rock Desert, N. W. Nev.; Clear Lake, Cal.; and Cove Creek, S. W. Utah. Used in making H^2SO^4; matches; gunpowder; as a cement; in copying medals; in vulcanizing rubber; and in medicine.

5. Gypsum, found as an usual attendant of salt deposits, though sometimes deposited from solution when no salt followed; and again as a product of the change of limestones by H^2SO^4. Salina Gr. and L. Helderberg in N. Y. and Ohio; Sub-Carboniferous in Mich., Nova Scotia, and Va. (?); Carboniferous, Ft. Dodge, Iowa; Permian, Kan. and Trias. far west. Used for fertilizers and for Plaster of Paris.

6. Mica, from very coarsely crystalline granite of Archaean. (Min. Res. of U. S. 1882, p. 583.) N. C. in Yancey and Mitch-

ell Co.'s produces very fine, some of the crystals reaching even 1000 lbs. On the sites of ancient workings. Canada also produces some (Rep. 1863, p. 795.) Siberia affords it largely. Deadwood, Dakota, etc.

Used for windows of stoves, lanterns, and war ships, lamp chimneys, ornaments, wall-paper finish, lettering signs, etc.

7. Corundum, in metamorphic rocks, mica schists and granular limestone (Dana); associated in western N. C., Clay Co., Ala., etc., with chrysolite rocks and chloritic minerals. Obtained from N. C., from Chester, Mass., Smyrna and Naxos, Ceylon, Ava, and East Indies.

Uses: finer varieties are gems, ruby, emerald, etc.; coarser used as emery.

8. Talc, in metamorphic rocks along Atlantic States; Pa. and Ga. chiefly; also St. Lawrence Co., N. Y. (See Min. Res. of U. S. 1882, p. 585.) Product of 1882 estimated at 50,000 tons at $12.00.

Uses: largely for soap-making, and dressing fine sheep skins, gloves, etc.; also in paper-making, and somewhat for lubricants.

J. B. Woodworth
with the author's
compliments

A SYNOPSIS

OF A

COURSE OF LECTURES

ON THE

Elements of Historical Paleontology,

DELIVERED AT

CORNELL UNIVERSITY,

1885–86.

H. S. W.

ITHACA, N. Y.,
ANDRUS & CHURCH,
1886.

Historical Paleontology.

1. Fossils :

[a]What are they? [b]From the geologist's point of view. [c]From the biologist's standpoint? [d]How considered in present course of lectures. [e]Importance of the study of fossils.

2. [a]Early knowledge of fossils. [b]In what respects imperfect. [c]When were fossils first clearly understood?

3. Cuvier :

[a]His observations in 1796. [b]His work of 1812–13, and its relation to the rise of the Science of Paleontology. [c]Why was he specially fitted to interpret fossils.

4. Who immediately followed Cuvier?

5. When and where the term Paleontology was first used?

6. The supposed nature of fossils before Cuvier.

7. What progress in science was essential before Paleontology could arise?

8. [a]What were the striking features of progress in the study of Natural History in the early years of this century? [b]Who were the leaders in the study of invertebrates? [c]Who developed the study of plants? [d]The results of their studies.

9. William Smith, 1816–20; his contribution to the Science.

10. Murchison & Sedgwick, 1839–55; their part.

11. The relation of stratigraphic geology to pure paleontology.

12. Paleontology :

[a]Its true scope. [b]The extent to which fossils are valuable in identifying strata and geological age. [c]Paleontology as an historical study. [d]Paleontology as a systematic science.

13. What preparatory study essential to its profitable pursuit?

14. Why separate it from Geology?

15. Why history of organism, and not ancient history?

16. Stratigraphy and Paleontology are intimately associated and should be studied together.

Note, [illegible]
[illegible]

17. Organisms: what facts in regard to them of special interest to the paleontologist?

18. The chief topics to be considered in these lectures:

[a]The method of study. [b]The relative importance of the several kinds of facts presented. [c]Necessity of work outside the lecture-room. [d]Use of charts and specimens.

19. Text books; qualities demanded, where to be found.

20. The scientific use of generalizations *versus* the superficial treatment of science.

21. Geologic time:

[a]Its subdivisions, how determined? [b]Stratigraphical succession the fundamental criterion of length and order of time. [c]The classification of the strata forms the basis for the chronologic divisions.

22. [a]The system of nomenclature adopted by the International Congress. [b]How different from that in common use in America as illustrated in Dana's Manual.

23. Reason for recognizing nine chronologic divisions, corresponding nearly to the Periods of the international nomenclature.

24. Relative length of duration of the Periods; how determined?

25. Diagrammatic representation of the relation between the duration of the Periods and the progress in rank and variety of form of the organisms inhabiting the globe. (See p. 5.)

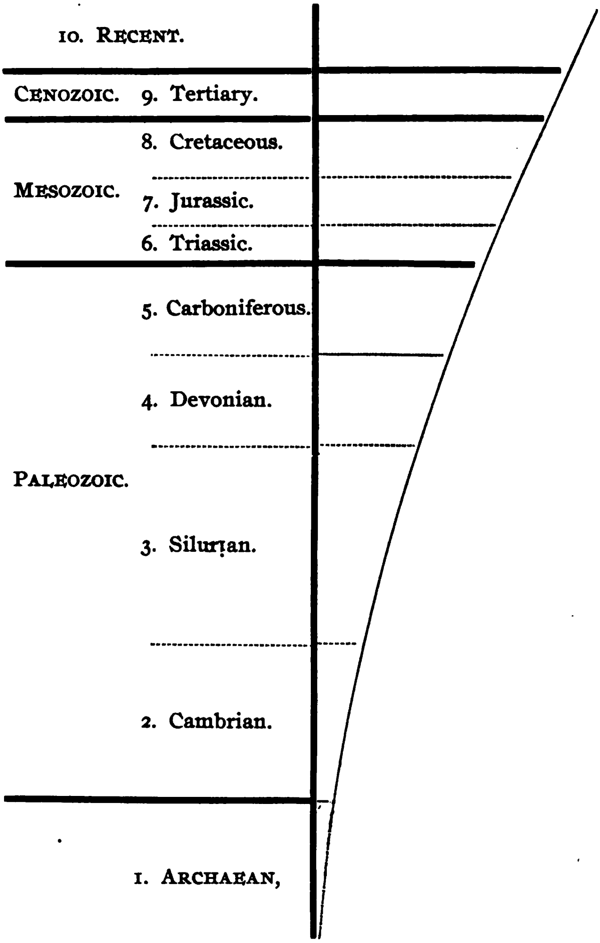
26. Usage of the terms Horizon, Zone, Stage, Group, Formation, Period, Age, Fauna, Flora.

27. Fossils:

[a]Lyell's definition. [b]Origin of the name. [c]Its later usage. [d]Examples of present usage. [e]Hard-parts of animals. [f]Classification (of C. A. White): (1) Fossils proper; (2) moulds (or internal or external impressions); (3) casts; (4) pseudomorphs. [g]The occasional use of the term "cast. [h]Crushing and distortion of fossils. [i]Metamorphism.

28. [a]Imperfection of the fossils, and of the record. [b]What do they represent, [c]and in what particulars is the historical record necessarily deficient?

29. The classes of the Animal Kingdom having fossil representatives. (See p. 6.)



DIAGRAM

Representing the relative length of the Geologic Periods, and 'the progress in the rank and variety of form of the organisms inhabiting the globe.

List of the Classes of the Animal Kingdom represented in the fossil state, with their Geologic Range.

PROTOZOA.
  1. Rhizopoda.
COELENTERATA.
  2. Spongia.
  3 Actinozoa (=Anthozoa.)
  4. Hydrozoa (=Polypomedusa.)
ECHINODERMATA.
  5. Crinoidea.
  6. Asteroidea.
  7. Echinoidea.
  8. Holothurioidea.
VERMES.
  9. Annelida.
MOLLUSCOIDA.
  10. Bryozoa(=Polyzoa.)
  11. Brachiopoda.
MOLLUSCA.
  12. Lamellibranchiata
  13. Gastropoda.
  14. Pteropoda.
  15. Cephalopoda.
ARTHROPODA.
  16. Crustacea.
  17. Arachnoidea.
  18. Myriapoda.
  19. Insecta.
VERTEBRATA.
  20. Pisces.
  21. Amphibia.
  22. Reptilia.
  23. Aves.
  24. Mammalia.

30. [a]Relation of habitat to the preservation of fossil remains. [b]Marine faunas. [c]Brackish water faunas. [d]Faunas and floras of land, and of fresh water.

31. Geographical distribution and provinces.

32. Geological range.

33. The relative completeness of the record for the several groups of organisms.

34. Special value of invertebrates for historical study.

35. Common and abundant forms as compared with rare and unique forms.

36. Facts worthy of particular note in regard to the organisms of each period : [a]Dominant forms. [b]First appearance or initiation of new types. [c]Decrease and extinction.

37. Geologic periods not marked off by sharp lines.

38. The importance of the Paleozic records in the study of the history of Organisms.

39. Most of the types of the Animal Kingdom begin in the Paleozoic era.

I, THE ARCHAEAN.

40. [a]Character of the rocks. [b]Thickness of the deposits in Canada. [c]How deposited, and present condition. [d]The names Archaean and Eozoic. [e]Sources of information in regard to the Archaean record.

41. Evidences of organic life:

[a]The structure and character of the rocks. [b]The limestones, their thickness and interpretation. [c]Graphite. [d]Iron ares. [e]Eozoon, its discoverer, when found, description, what it resembles, opinions as to its nature ; theory as to its mode of preservation. [f]Other supposed organisms.

42. The supposed successors and the systematic relations of the Eozoon.

43. Foraminifera as limestone builders.

44. Variability and persistence of the characters of foraminifera.

45. Summary.

56. 2 - See 102^a note.

II, THE CAMBRIAN.

46. [a]The Cambrian system of Sedgwick. [b]The Primordia Zone and Fauna of Barrande. [c]The fauna and its limits. [d]The interpretation of the Cambrian of America (Walcott). [e]The grand cañon section and the Tonto group.

47. The two grand life-periods of the Paleozoic and their characteristics :

[a]Cambrian—Silurian ; abundance of Trilobites, Graptolites and Brachiopods, and absence of Vertebrates.

[b]Devonian—Carboniferous ; abundance and variety of Fishes and Amphibians, the disappearance of Graptolites and Trilobites, and finally the abundance of cryptogamous terrestrial life, or Flora.

48. The subdivision of the Cambro-Silurian.

49. The Murchison-Sedgwick controversy.

50. Limits of the Cambrian in America.

51. Paleontologic reasons for including part of the "Canadian Period" of Dana in the Cambrian.

52. The number of species recorded.

53. The typical British series, and the order of first appearance of the several classes and orders.

54. The Swedish section.

55. The section in Bohemia.

56. Relative prominence of the several classes in the Cambrian fauna : (1) Trilobites, (2) Brachiopods—the Tretenterate division, (3) Pteropoda, (4) Crustacea, other than Trilobites, (5) Cystidians, (6) then follow other Brachiopods, Sponges, Annelids, Gastropods, Graptolites, and Cephalopods.

57. Tabular view of the Animal Kingdom, (See Chart, and p. 6.) shows that all the branches of the Animal Kingdom were represented in the Cambrian fauna, except the Vertebrates.

58. Trilobites ; description of the structure of the Trilobite. (*Head* or *Carapace*, glabela, cheeks, eyes, facial suture, furrows, lobes, rostral shield, hypostoma ; *Thorax*, axis, pleura, facets, pleural groove, fulcra ; *Pygidium*, segments, limbs ; *Appendages*, (of Walcott), ventral membrane, intestinal canal, hypostoma, mouth, head appendages, thoracico-abdominal appendages, ambulatory legs, epipodites, branchia.)

67. [illegible] or [illegible] [illegible]

59. Classification (of Salter) based on facial suture and eyes.

60. Early views about Trilobites.

61. Their geologic range.

62. Their position in the Animal Kingdom.

63. Range of the various orders of Crustacea.

64. The Annelida of the Cambrian.

65. Representative Trilobites of the Cambrian:

(1) Paradoxides, (2) Conocephalites, (3) Agnostus, and their respective families; characteristics of 1 and 2, and differences; same of Agnostus.

66. Historic laws deduced from the study of Trilobites.

67. Literature for fuller study of the subject.

68. Ostracoids and Phyllopods (Hymenocaris).

69. Mollusca and Molluscoida.

70. Brachiopoda:

[a]Tretenterata and Clistenterata. [b]Characters of the whole class, distinctions separating the two orders, (equilateral, bivalved, with or without peduncle, alimentary canal, complicated brachial apparatus, "blood channels," "pseudo hearts," numerous muscles). [c]Lingula and Discina still living. [d]Climax of the tretenterate Brachiopods. [e]Clistenterata begin in the genus Orthis.

71. Gastropoda—characters of. See genera Pleurotomaria, Euomphalus, Murchisonia, belong to the "Vegetarian Repentantia" of Lankester.

72. Free swiming Mollusca:

[a]Pteropods, represented by Theca and Conularia. [b]Cephalopods, by Orthoceras. [c]Lankester's views of the relations of these classes. [d]Their characters.

73. Lamellibranch's doubtfully represented.

74. Conclusions. The high character of the classes and the variety of forms presumptive evidence of previous life.

75. Absence of limestone may account for absence of some groups, viz., corals, etc.

76. Plants represented by Fucoids and Oldhamia.

77. Most of the classes represented by only a few traces, and begin in abundance in the Silurian.

78. Conspicuous law as to the rank of the early forms. The higher classes represented by their lower orders.

79. Prominent genera of the Cambrian: Paradoxides, Lingulella, Archaeocyathus, Obolella, Hymenocaris, Oldhamia, Scolithus, Sao.

80. Important genera beginning in the Cambrian are Orthis, Discina Pleurotomaria, Hypolithes (Theca), Lingula, Leperditia, Agnostus.

81. Some doubtful forms referred to Cystids, Crinoids, Orthoceras, and Graptolites.

III, THE SILURIAN.

82. Characteristics of the life of the System ; great abundance and variety of marine life: rocks richly fossilferous.

83. Comparison between the history of the Trilobites and of the tretenterate Brachiopods.

84. The Silurian fauna:

[a]The great majority of its families and genera now extinct. [b]Thirty-one of the ninety-seven orders of fossil animals are known to have appeared before the close of the Silurian [c]Representatives of the majority of orders still living. [d]Mostly marine. [e]Dominant types—Mollusca and Brachiopods. [f]Highest types—Crustacea and Cephalopods. [g]New types initiated—Actinozoa, and before the close, traces of Vertebrates, and a land flora (Lycopods).

85. Recent discovery of Scorpions and Insects.

86. The Silurian system of Murchison.

87. Character of the rocks in Britain, in America. Maximum thickness.

88. Approximate number of species, (in 1868):

Brachiopds,	1600
Trilobites,	1600
Cephalopods,	1400
Gastropods	900
Lamellibranchs,	700
Actinozoa,	500
Echinodermata,	500
Polyzoa, Heteropoda, Entomostracans, each between	200 and 500

Other classes under 200 each, total about 10,000 species.

89. Graptolites, Cystids, and Entomostracans, form a conspicuous feature of the fauna.

90. Range of the classes of the Animal Kingdom, (see list, p. —).

91. Irregularity in the usage of the terms Branch, Class, Order.

92. Genus the most satisfactory unit of systematic classification.

93. Graptolites:

[a]Initiation in Cambrian ; climax in Silurian ; extinction near the close—(lower Devonian, Kayser.) [b]Classed near the Sertularians. [c]Found in "black" or "alum" shales or "slates." [d]Characters : polypary, "solid" axis, cellules, central disc, monoprionidian, diprionidian. [e]Dictyonema.

94. Actinozoa (corals) :

[a]Range of the main types of the Silurian. (Chaetetes, Favosites, Halysites, Syringopora, Cyathophylum, and the Rugosa.) [b]Distinctive characters : walls, septae, tabulae, perforations, corallites, simple, massive, or compound, fossula, dissepiments. [c]Generic and specific differentia.

95. Echinodermata :

[a]Range of the principal types : Cystidians, Crinidians, Blastoids, Asteroids, Echinoids—(Archaeocidaris, Cidaris, and the irregular Echinoids.) [b]Typical characters, and their modifications and homologies in the several orders. [c]Essential characters, anatomical, and of the hard parts, mouth and oral end, aboral end and anus.

96. Typical arrangement of parts in a sea-urchin :

[a]Ambulacral rows, five pairs of two each. [b]Interambulacral plates, five rows of two pairs. [c]Apical disc, genital, ocular and anal plates.

97. Ambulacra :

[a]Ventral position of, in Asteroids.[b] confined to central disc in Ophiurans.

98. Crinoids :

[a]Stalk and calyx, openings all ventral and within base of arms. [b]Genetal system.

99. Cystidians—calyx irregular, arms wanting or rudimentary, valvular pyramid, hydrospires.

100. Blastoids—pseudoambulacra, regular plates few.

102 1/10 of the lime of the Keokuk & St. Louis limestones separated by Bryozoa. - Shaler - M.H. 14. 256
-1888-
Silicious nodules of same horizon [illegible] traced to metamorphism of silica-fixing Bryozoa. loc. cit.

102a Protremata - Inarticulata, Crania, Discina, Lingula -
Clistenterata = Articulata, Spirifera, Terebratula, etc -
Lineage of Brachiopods. Stroph d.

104 T, [illegible]

[illegible] [illegible] Shaler, M.H. 14 [illegible]
c. Cce: [illegible]

107. Relation to Phyllopoda in the indefinite segmentation of body & in likeness of appendages [illegible] (?) [illegible] impression of compound & sessile eyes, thoracic branchiae & (?) nature of mouth organs.

a. Larva of modern Limulus has resemblance to [illegible] Trinucleus.

101. The generic and specific differentia of Crinoids and Cystids, and their classification.

102. Brachiopods:

[a]The two divisions Tretenterata and Clistenterata. [b]Range of the principal families: 1. Lingulidae; 2. Obolidae; 3. Craniidae; 4. Orthidae; 5. Strophomenidae; 6. Rhynchonellidae; 7. The genus Spirifera, and the spiral bearing Brachiopoda; 8. Productus and allied genera; 9. Terebratulidae. [c]Generic and specific differentia of Brachiopoda.

103. Law of the initiation of new forms, and the history of Brachiopoda.

104. Cephalopoda:

[a]The two orders, Tetrabranchiata and Dibranchiata. [b]Prominent characters of the class and of the orders. [c]The shell, its several parts, a chambered cone, septae, siphuncle, sutures, body chambers, aperture, sutures, lobes and saddles, (dorsal) external and (ventral) internal aspect of the coiled shells. [d]Subdivisions of Tetrabranchiata: 1. The Nautiloidea, (sub-order) mainly Paleozoic. 2. The Ammonoidea, mainly Mesozoic.

105. The Nautiloidea. For classification see Zittel.

[a]Fam. Nautilidae, proper, more conspicuous in later Paleozoic. [b]Fam. Orthoceratidae, a dominant Silurian family. [c]The characters and range of the genera: Nautilus, Lituites, Trochoceras, Clymenia, Orthoceras, Cyrtoceras, Phragmoceras, Gomphoceras, Endoceras. [d]Generic and specific differentia.

106. Remarks upon the studies of Hyatt and others, and the forms Orthoceran, Cyrtoceran, Gyroceran, and Nautilian, and their historical importance.

107. Order of initiation, and range in time of the several types; actual observed order, and order of prominence of each.

108. Trilobites:

[a]The differentia, generic and specific. [b]General law as to the initiation of new types. [c]Prominent Silurian genera: Acidaspis, Harpes, Calymene, Lichas, Asaphas, Bathyurus, Illaenus, Cheirurus.

109. Merostomata:

[a]Limulus, a modern representative. [b]The fossil sub-or-

109.c. Commenced in Up. Silurian. = Neolimulus falcatus Woodw.
Vd. Nicholson Man. Ed. 3rd. I p. 325. fig. 241.
No traces detected in Devonian yet. - Ib.
Occurs in sev. types in Carb. - Ib. = Euproöps Danae.

ders : Eurypteria, its ordinal and sub-ordinal characters, and historical position. [c]Xiphosura, characters and range.

110. Tentaculites—a pelagic form ; characters.

111. Lamellibranchs :

[a]Prominent Silurian genera : (Monomyaria) Avicula, Pterinea. [b](Dimyaria) Modiolopsis, Ctenodonta, Orthonota, Palearca.

112. Gastropods :

[a]Prominent genera : Murchisonia, Platyceras, Pleurotomaria.

113. Relative importance, in the Silurian, of the different types of Mollusca :

[a]Cephalopods, Pteropods, and Heteropods, the more dominant groups. [b]Prominence of pelagic forms, (as Bellerophon (?) Macluria, Ophileta, Theca, Conularia, Tentaculites.

114. Geographical differences in the range of species.

115. The Silurian system in different regions.

IV, THE DEVONIAN.

116. [a]The upper limit of Murchison's Silurian system, and [b]Conrad's application of it in New York, (1841), [c]Vanuxem's (1842) Erie division of the New York System, [d]Hall's usage, (1843–1846). [e]Lower limit of Devonian, (1846). [f]Oriskany sandstone, why the base of De Verneuil's Devonian, (1847) ? [g]Oriskany, why the top of Hall's Silurian, (1859) ? [h]Present usage.

117. The Devonian and the old Red Sandstone of English geologists.

118. These discussions illustrative of the importance of bringing lithologic, stratigraphic, and geographic facts to bear upon the interpretation of paleontologic history.

The marine invertebrate fauna of the Devonian.

119. Stony corals, (Actinozoa) :

[a]Genera : Cyathophyllum, Zaphrentis, Favosites, etc. [b]Absence of the genus Halysites.

120. Hydrozoa :

[a]Dictyonema. [b]Monograptus recognized in lower Devonian in Prussia, by Kayser,

121. Crinoids:

[a]No great change in genera from the Silurian fauna. [b]Cystids wanting. [c]Blastoids few.

122. Mollusca and Molluscoida:

[a]An increase in the numbers of Gastropods and Lamellibranchs. [b]Cephalopods the most prominent group. [c]Brachiopods the most common of invertebrates, as they were in the Silurian.

123. Prominent genera of Cephalopoda: Orthoceras, Cyrtoceras, and Gomphoceras, and Goniatites and Clymenia, which were characteristic of some zones and are essentially Devonian types of Cephalopods.

124. Brachiopods:

[a]Prominent genera: Spirifera, Orthis, Strophomena, (Hall's genus Strophodonta). [b]The Productidae and Terebratulidae began to be conspicuous. [c]The genera Terebratula, Cryptonella and Productus are new.

125. Crustacea:

[a]Trilobites declining, prominent genera were Homalonotus, Phacops, Proetus, Bronteus. [b]Ostracoids abundant in some zones.

126. Vertebrates:

[a]The first age in which fishes were at all abundant, some traces of them below. [b]Placoderms the most conspicuous type.

127. Land plants:

[a]Lepidodendron. [b]Ferns. [c]Conifers. [d]Calamites.

128. The marine invertebrates with substantially the same families as in the Silurian.

129. The grand features of Devonian life are seen in its Vertebrates and Land Plants.

130. Vertebrate life of the Devonian. (See Newberry's views and classification, Paleontology of Ohio, Vol. I.; Nicholson's Paleontology, Vol. 2. See also chart of classification and range prepared for the class).

[a]Fish—slight traces below the Devonian. [b]Devonian fish large, abundant, and highly organized in some cases. [c]Placoderms and some Elasmobranchs first became conspicuous. [d]Ganoids most prominent between the Devonian and Jurassic. [e]Tele-

osts most prominent between the base of the Cretaceous and the present. [f]The very earliest fossil fish, (Q. J. G. S. XLI., p. 48), probably allied to modern Cestraciont Sharks. [g]The Chimeroids.* [h]The Ganoids. [i]The Crossopterygidae. [j]Dipterus. [k]Holoptychius. [l]Ctenodont teeth. [m]The Chondrosteidae. [n]The Cephalospidae. [o]The Placoderms. [p]Pterichthys. [q]Dinichthys.

131. Devonian Plants : Classification of Fossil Plants and their range in the Paleozoic. (For general classification see Lesquereux, Principles of Paleozoic Botany, 13th Geol. Rep't of Indiana 1884 ; also, Zittel, Handbuch d. Pal. II., 1879–84).

132. Reasons for recognizing a special classification for the botany of fossils, and its necessity for the general treatment possible in these lectures.

133. Lesquereux estimates 6,000 fossil species, 150,000 living. Not over 50 species to square mile in the United States ; 140 to 200 species seen in some single coal beds.

134. Four epochs of successive development : 1. Reign of Thallasophites, Silurian ; 2. of Vascular Cryptograms, Devonian—Carboniferous—Permian ; 3. of Gymnosperms, mid-Permian—Jura ; of Angiosperms, Cretaceous—recent.

135. Devonian Floras :

[a]Algae, Uphantaenia, Dictyophyton, Spirophyton. [b]Acrogens; (1) Equisetacea, (Calamites, Asteriophyllites, Annularia, Sphenophyllum) ; (2) Ferns, (Shimper's Brongniart's classification of fossil ferns) : Neuropterideae, Adiantideae, Sphenopterideae, Pecopterideae; (3) Lycopodiaceae : Lepidodendron, Lycopodites, Ulodendron, Knorria, Sigillaria, Stigmaria. [c]Prototaxites. [d]Conifers. [e]Cycads, (? in Devonian).

136. Insecta :

[a]Centipedes. [b]Spiders. [c]Scorpions (in the Silurian also).

137. [a]Tribes of animals rarely seen above the Devonian : Cystids, Trilobites, Orthoceras, Halysites, Favositidae, Chaetetes.

***Note.—The mention of a family or generic name in this synopsis, indicates the description and illustration of the essential characters of and the more important secondary characters which furnish specific differentia for the genus.**

139. See "the [illegible] [illegible] [illegible] [illegible]" Dawson, 1888, p.

142 [illegible] [illegible] [illegible] [illegible] 32, fig. 46B.
[illegible] [illegible] [illegible] [illegible] [illegible] but not [illegible] carb. lk. 307.
Foraminifera [illegible] [illegible] diam. 4 feet limestone
of sub-Carb. S. of Africa extant [illegible] [illegible]

[b]Among Brachiopods, Orthis, Strophomena and their allied genera rarely seen above the Paleozoic.

138. Conspicuous features of [a]the Devonian Fauna are Spirifera and Orthis, in association with Productus and Terebratula, Goniatites, Placoderm Fish; and of [b]the Flora, Psilophyton and an occasional Lepidodendron.

139. Dawson's conclusions from the study of Devonian Plants.

V, THE CARBONIFEROUS.

140. [a]The nature of the transition from the Devonian. [b]The general order of the series of deposits. [c]Two groups of deposits with distinct character to their fossils. [d]Sub-carboniferous or Lower Carboniferous. [e]Carboniferous proper or Coal measures. [f]Permian.

141. The marine fauna of the Carboniferous was conspicuous for Crinoids, certain corals, a few genera of Brachiopods.

142. Characteristic features of the fauna : Protozoa ; Fusulina, Nummulina, Saccamina.

143. Corals : (1) Rugosa and Tabulata rare ; (2) Lithostrontion, Philipsastrea and Lonsdaleia characteristic ; (3) Zaphrentis, Cyathophyllum and Amplex occasional.

143. Fenestellidae (Archimedes).

144. Echinoderms: (1) Melonites, (2) Archaeocidaris, (3) Blastoids, (4) Crinoids,—Platycrinus, Actinocrinus, Cyathocrinus, Poteriocrinus, Forbesiocrinus. (Three hundred and fifty species of Crinoids recorded from the Burlington limestone, Iowa.)

145. Brachiopods : Productus, Spirifera, Terebratula, Rhynconella. the prominent genera.

146. Mollusca :

[a]Prominent Lamellibranchs were Aviculopecten, Leda, Nucula, Conocardium, Modiola. [b]Common Gasteropods were Natica, Pleurotomaria, Loxonema, Euomphalus. Bellerophon was frequent. [c]Goniatites conspicuous among Cephalopods.

147. Crustacea :

[a]Trilobites, rare and small, few genera. Griffithides and Phillipsia the main genera. [b]Ostracoids—Beyrichia, Leperditia, etc. [c]Entomostraca—Phyllopods, Eurypterids, and a few Xipho-

145 a. [illegible]

152a Θήκη, case. b. a [illegible]

[illegible]

c. [illegible]

sura. [d]The higher Crustacea represented by the macruran Anthrapalaemon.

148. Vertebrates :

[a]Sharks—cestraciont and hybodont. [b]Ganoids less conspicuous. [c]A prominent feature, the general absence of the Placoderms. [d]Sauropus, regarded as tracks, the earliest trace of an Amphibian.

149. Special flora of the coal measures :

[a]The character of the deposits. [b]Principal types—Equisetacea, Lycopodiacea and Ferns ; Conifers appear but are rare.

150. Permian flora adds the Conifers and Cycads as prominent features.

151. Fauna associated with the Carboniferous flora.

[a]Fresh water and land Mollusca,—Pupa, Anthracosia. [b]Scorpions, Myriapods, Neuroptera, Orthoptera. [c]Fish—Ganoids and Selachians. [d]Reptiles — labyrinthodont Amphibians and Lacertilia (Eosaurus).

152. Permian, some new features in the fauna and flora :

[a]Protosaurus, a thecodont reptile ; [b]Walchia, Psaronius ; [c]Annularia and Conifers prominent : Conifers (Dadoxylon, Ullmannia, Pinites) ; [d]Sigillarids rare ; [e]no Goniatites.

153. Conclusions. (See Dana's Manual, pp. 382–389.)

VI, VII, VIII, MESOZOIC.

154. The Paleozoic-Mesozoic line not sharply defined in marine faunas.

155. Many prominent paleozoic genera cease to be conspicuous, are rarely, and in some cases never seen again. (See as examples Lepidodendron, Sigillaria, Calamities, the Trilobites, Graptolites, Cystidians, Goniatites, the genus Productus, Tabulate and Rugose Corals, the Placoderms, and the genus Orthoceras.)

156. The Terebratulids and the Rhynchonellids are the prominent families of Brachiopods.

157. The old type of Crinoids—Paleocrinoidea—ceases.

158. A few marine genera extend from the Paleozoic to recent time.

159. Relative length and importance of the subdivisions of the Mesozoic,—Triassic, Jurassic, Cretaceous.

168. 4-gills- 40+ short tentacles, external chambered shell. Septa connected by "siphuncle".

169. Flat-spiral — coils in a [illegible] siphuncle dorsal. folded septae, St. Dev- Carb. — Chalk — above the [illegible] in India.

160. Mesozoic Protozoa—Orbitolina, Nummulinidae, Globigerina, Textularia. (See also Diatoms and Desmids.)

161. The nature of green-sands.

162. Coelenterata :

[a]Sponges and [b]Corals, (Actinozoa)—Astraeidae, Fungidae, Aporosa, Madrepores—Perforata.

163. Echinodermata :

[a]Crinoids—Encrinus. Pentacrinus, etc. The Pychnocrinoidea of Pictet. [b]Starfish. [c]Echinids, regular, as Cidaris ; irregular as Spatangus ; sessil forms, Marsupites, and free Saccosoma, like the Comatulas.

164. Brachiopoda were restricted, with few exceptions, to the families of the Terebratulas, Rhynchonellas, Discinas, Lingulas, and Cranias.

165. The prominent Lamellibranch families : Trigonidae, Ostreidae,—genera, Ostrea, Gryphea, Exogyra.

166. The Hippuritidae, (Rudistes, etc.).

167. Gastropods—all except a very few families were represented before the close of the Mesozoic.

168. Cephalopods—first order, Tetrabranchiata :

[a]First sub-order, Nautiloidea, mainly Paleozoic. Only two families pass the limit of the Paleozoic, viz. : Orthoceratidae, (gen. Orthoceras), and Nautilidae (genera Nautilus and Aturia). [b]Orthoceras known in the Mesozoic in only a single region, —the St. Cassian beds—but is there associated with the Ammonoidea. [c]Nautilus reaches its culmination in the Mesozoic.

169. Second sub-order, Ammonoidea, mainly Mesozoic.

170. Of the Dibranchiata—second order—the first sub-order, Decapoda, was mainly Mesozoic. One family, the Sepiophora, did not appear till the Tertiary.

171. The second sub-order, Octopoda—example Argonauta—left no traces earlier than the middle Tertiary.

172. Of the Ammonoidea a few families of [a]the Prosiphonata have been represented by species from the deposits, called Permo-Carboniferous in India, (the salt-range group, see Waagen's Report,) and [b]the two retrosiphonate families—Clymenia and Goniatites—are confined to the upper Paleozoic, but [c]the great mass of species and genera are Mesozoic.

b Octopoda – 8-arms. fixed eyes.
Argonauta, Octopus
a Decapoda – 10-arms. movable eyes.
Loligo, Sepia.
Cuttle-fish = Sepia officinalis.

177 - phragma = partition

173. Second order, Dibranchiata:

[a]Of the sub-order, Decapods, all the families, except Sepiophora, began before the close of the Mesozoic. [b]The sub-order Octopoda—Argonauta is not recognized below the later Tertiary.

174. The various characters adopted by different authors as criteria of classification, such as the position of the siphon, the degrees of coiling or curvature of the shell, the sutures, etc., their relative values, and their relation to theories of interpretation of the Ammonites.

175. The necessity, in studying the history of organisms, of taking note of the degree of plasticity the characters exhibit when found under the same conditions, and at a single stage.

176. Classification and range of the Dibranchiata.

177. The Phragmophora (Belemites, etc.).

178. Arthropoda of the Mesozoic:

[a]Lobsters. [b]Shrimps. [c]Crabs. [d]Beetles. [e]Butterflies. [f]Grasshoppers.

179. The cases of the Scorpion lately found in the Silurian, a Trilobite in the Mesozoic and a Cystid dredged from the deep sea, suggestive of caution in trusting negative evidence as to exact limits of initiation or extinction of groups of organisms.

180. Reptiles:

[a]Huxley's Classification. [b]Labyrinthodonts, placed with Amphibians in the province Ichthyopsida. [c]Sauropsida—a province including Birds and Reptiles. [d]Chelonia. [e]Plesiosauria. [f]Lacertilia. [g]Ophidia. [h]Ichthyosauria. [i]Crocodilia. [j]Dicynodontia. [k]Ornithoscelida. [l]Pterosauria.

181. Characters important in classification and history:

[a]Of the vertebrae,—amphicoelian, opisthocoelian, and procoelian. [b]Of the teeth—labyrinthodont, pleurodont, acrodont, thecodont, maxillary, palatine, pterygoid and vomerine teeth. [c]Of the jaw—(1) each ramus a single bone, (2) or of several bones anteriorly united by anchylosis, ligament or muscle, (3) joint in middle of ramus, (4) proximal articulation, by quadrate bone, or direct, (5) the occipital condyle, single in the Saurosida, two in Amphibia.

182. For each order—the prominent characters, an age of initiation, an age of culmination, an age of extinction.

183. Avian Reptiles, and Birds :

[a]Triassic—Jurassic, Avian Reptiles, (1) Ornithoscelida—Dinosauria, Compsognatha ; (2) Pterosauria—Pterodactylus, Dimorphodon, Ramphorhynchus and Pteranodon (Cret.), Archaeapteryx. [b]Cretaceous—Reptilian Birds and Birds ; (1) Odontornithes—Hesperornis, Ichthyornis and (2) a few genera of the swimming (Natatores), and of the wading (Gallatores), Carinatae. [c]Tertiary—with the Tertiary the first initiation of the other orders of Carinatae—the Rassores, the Scansores, the Insessores, the Raptores, as well as most of the families of the Natatores and Grallatores, also the non-flying birds—the Ratitae.

184. Ornithoscelida:

[a]Tracks in Triassic regarded as Dinosaurian. [b]Bird-like characters seen in the anterior extension of the Ilium, the slender and backward prolonged Ischium, and in several characters of the hind limb bones.

Toothed Birds :

185. Odontopteryx, only serrated bill, no true teeth.

186. Hesperornis, lower jaw fully toothed, upper jaw, back part toothed, front part bill, teeth in sockets.

187. Ichthyornis, carinated sternum, amphicoelian vertebrae. (Pteranodon, a flying reptile,—Cretaceous—with bill, no teeth. See 191.)

Flying Reptiles :

188. Pterosauria, teeth and wings, "patagium" as in bats, pneumatic cavities in bones as birds.

189. Pterodactylus, fully toothed.

190. Rhamphorhynchus, only back part toothed.

191. Pteranodon, no teeth. (See 187.)

192. Birds ; class characters and classifications.

193. Archaeopteryx.

104. Odontornithes.

195. Ratitae. (? Dinornis, etc.)

196. Carinatae :

[a]Natatores—Albatross, Swans, Cormorants, etc. [b]Gral-

195 [illegible] [illegible] May
[illegible]

201 Persian [illegible] = [illegible] [illegible] [illegible]
Art [illegible] [illegible] [illegible] [illegible]

latores—Sandpipers, Rails. The other orders, [c]Rasores, [d]Scansores, [e]Insessores, and [f]Raptores did not appear till the Tertiary.

IX, THE TERTIARY.

197. Mammals, [a]except Marsupials, begin in Cenozoic. [b]Essential characters of the class. [c]Ordinal characters, i. e., differentia seen in various modes (1) of birth and early care of young, (2) of progression,—feet and limbs, (3) of defense and attack,—teeth and horns. [d]Significance of milk secretion ; of hair ; importance of characters of the occipital condyle. [e]Study of the chart of classification and history of Mammals.

198. Monotremes—bird-like in some points of structure, and in function of ovapositing—first trace of in Post Pliocene.

199. Marsupials—the first mammals, appear in early Trias, prominent in Mesozoic ; significance of Marsupium.

200. Cetaceans, (Zeuglodon) marine.

201. Ungulata, both Perissodactyls and Artiodactyls, first appear in Eocene, and with modern families of Rhinoceros, Tapir, Horse, Swine, Musk-deer ; the other families nearly all represented before Pliocene.

202. Dinoceras, etc.

203. Proboscidians, the three types appear in Miocene.

204. Carnivora ; first in Eocene, the perfect cats among the first ; almost all its families in Miocene.

205. Before the close of the Miocene all the orders of Mammals except Man have appeared.

206. Review of the history of Organisms :

[a]Progress in organic structure coördinate with the geological development of the environment, [b]early inhabitants purely marine, [c]the presence of coasts, of fresh water from lands, of dry land, of air, each recorded in an increased complexity of structure, and a fuller specialization of organs for special functions.

207. The law of plasticity, and the consequent adaptability of organisms to environment.

208. The law of heredity, and the perpetuation by generation of ancestral characters.

209. Food and population, the survival of the fittest.

210. Death the natural result of performed function.

211. Gradual evolution of new forms by intensification of varietal peculiarities.

212. Initiation of new types of organisms.

213. All Nature, inorganic and organic, studied historically, points to an origin and a Cause.

Man in the Tertiaries.

Science Vol II [illegible] Sept. 12-84

[illegible] Wormley – Univ. Pa.

First anthropoid apes in middle eocene, then other forms [illegible] [illegible] plants [illegible] [illegible] [illegible] others –

[illegible] [illegible] [illegible] further back

Arboreal habits of early man militated against the preservation of [illegible] [illegible] [illegible] birds –

The Miocene & Post miocene of [illegible] & India [illegible] [illegible] [illegible] [illegible] for [illegible] relationship to [illegible] species –

Lyell's [illegible] 11th Ed. vol II p. 487 –

Elasticity of body is opposed to intellectual [illegible] [illegible], while [illegible] of the same [illegible] [illegible].

[illegible] [illegible] [illegible]

References.

Lyell's Princ.

Orton's Geol. Revised

Le Conte's Elements

Lyell's Man. Geo

Dana's Ma
of Geol. 3rd. Ed

Nicholson.

Zittel.

T

Ithaca Falls

Lingula zone